

NOISE LEVELS IN THE OPERATING ROOM

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ABSTRACT

Monitoring during *anesthesia* improves patient outcome by increasing the anesthesia provider's awareness of actual and potential problems. Lack of vigilance has been reported to be responsible for up to 30% of major problems occurring during anesthesia. Excessive *noise* in the environment is a factor that may decrease provider vigilance, and the Anesthesia Patient Safety Foundation has recently identified noise in the *operating room* (OR) as a major area of concern. In this study the level of noise in one OR was measured and correlations between noise levels and anesthesia providers' ability to hear critical patient monitors are described. The four-week study took place in an orthopedic OR of a 90-bed military hospital in the midwest. Noise was measured continuously from the initial set up of the room to the completion of the last procedure of the day. Episodes in which the audible pulse oximeter monitor tone (set at 50% volume) was difficult to hear or could not be heard at all due to the high levels of noise were documented. Noise levels ranged from a minimum of 46.8db(A) to a maximum of 95.0db(A). Average levels of noise (Leq) ranged from 60.1 to 69.4db(A). Baseline monitor tones and alarms ranged from 55-75db(A). NIOSH standards recommend the decibel level not exceed 85db(A) for an eight-hour work period or 91db(A) for more than two hours. Basic levels of noise measured in the OR did not exceed NIOSH standards. Determinations regarding the ability of noise levels to cause difficulty in hearing monitor tones and alarms were inconclusive. The role noise may play on decreasing anesthetist vigilance is still undetermined. Further study that focuses on actual noise levels and anesthetist task performance is needed.

Key Words: anesthesia noise operating room

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CHAPTER I: INTRODUCTION

Background

In the past thirty years, science and technology have afforded medicine and nursing countless new tools and machines that have allowed patients to undergo surgical procedures with improved outcomes. Unfortunately, these beneficial advances are associated with the corresponding noises that result from their use. In the United States nurses have been administering anesthesia since 1877 (Bankert, 1989). Today, Certified Registered Nurse Anesthetists (CRNAs) in the United States provide 75% of the estimated 40 million anesthetics given annually (American Society of Anesthesiologists, 1999; Martin-Sheridan & Wing, 1996). Thus, the adverse effects of noise in the operating room (OR) are an important problem to CRNAs.

Historically, nurses have been proponents of improvements in patient monitoring. Patients, including those in the OR, have benefited greatly from such improvements. CRNAs have had minimum monitoring standards set by the American Association of Nurse Anesthetists (AANA) since 1989 (AANA, 1999). Most of these require the use of patient monitors that have monitoring tones and alarms, with parameters set by the CRNA.

Noise comes from the same Latin root as the word nausea. Noise and its effects on man has been an issue for over 2500 years; Sybarites of Greece banned metal work involving hammering within the city limits as early as 600 BC (Kam, Kam, & Thompson, 1994). Romans had laws that specifically regulated noisy chariot traffic passing near residential areas at night. English common law recognized noise problems in the 13th

century in cases in which noise was termed a “nuisance” (Edelman & Genna, 1985, p.338).

Despite a long history of observing the negative effects of noise on man, first efforts to regulate noise in the United States did not occur until 1955. The United States Air Force was the first to establish regulations in 1956. The Walsh-Healy Public Contract Acts of 1936 referenced excessive noise but gave no limits for safe noise levels. In 1970, the Occupational Safety and Health Act (Public Law 95-164) was passed by Congress to provide safe environments for the working population of the United States. The National Institute for Occupational Safety and Health (NIOSH) was charged with the difficult task of determining safety and health risks in the work environment, and then recommending standards for exposure to the proper regulatory agencies. Finally, in 1972, NIOSH published “Criteria for a Recommended Standard: Occupational Exposure to Noise” which outlined standards for control of noise in the workplace. The current 1998 publication states that a workers eight-hour total weight average (TWA) should not exceed 85 dBA (NIOSH, 1998).

The nursing profession was not exempt from realizing the effects of noise. Florence Nightingale noticed an association between noise and patient discomfort (Nightingale, 1969). One aspect of noise is to create and manipulate patient environments to enhance their therapeutic potential (Pope, 1995). Today, CRNAs play an important role in determining the environment in the OR. Controlling excessive noise enhances the environment not only for the surgical patient, but also for the OR staff.

Little data exist regarding the actual levels of operating room noise. Current theories postulate that noise has a detrimental effect on efficiency and task performance (Davies

& Jones, 1985; Edsall, 1993; Eschenbrenner, 1971). This negative effect has also been demonstrated to occur with anesthesia providers in the OR (Kam et al., 1994; Murthy, Malhotra, Bala, & Raghunathan, 1995; Weinger & Englund, 1990). In this study, the levels of noise in the OR were measured, and compared to current NIOSH (1998) standards. By providing baseline knowledge in this area, future nursing research can be conducted to compare the effect of these levels on providers' efficiency and task performance.

Significance

Sounds are all around us. Sounds that most people consider unpleasant or unwanted are called "noise" (Hodge & Thompson, 1990). Vigilance is central to anesthesia providers in the operating room. There is an abundance of activity in the OR. The level of noise emitted from these activities can create a distraction for the anesthesia provider and may contribute to a lesser degree of vigilance.

Sources of OR noise include, ventilators, suction machines, monitoring devices, alarms, mechanical and pneumatic tools, as well as the clanging of metal bowls and instruments, and sterile carts (Hodge & Thompson, 1990). The Noise Handbook (Tempest, 1985) defines noise as "Sound undesired by the recipient", including "Sound which is harmful or interferes with normal activities, particularly with communication and efficiency." (p. xiii). The complex nature of the CRNA's role requires considerable vigilance and the potential for human error is ever present. Vigilant CRNAs must be completely aware of their patient's status at all times.

Current standards of practice in anesthesia include the use of monitoring devices for ventilation, oxygenation, cardiovascular status, and body temperature (AANA, 1999).

Technological advances allow manufacturers to install audible tones and warning alarms in these various monitors. CRNAs use these audible tones and alarms as a tool for monitoring patient status. Excessive noise in the OR has the potential to decrease the vigilance of CRNAs and inhibit their ability to hear audible monitors and alarms.

Few researchers have documented the levels of noise in the OR over the past decade. In other environments however, the effects of noise related to the human body, job performance, and hearing loss have been studied to a great extent. Noise is believed to have a negative impact on the body and job performance, and has even been considered a pollutant (Kam et al., 1994). In the study reported on this thesis, sound levels in the operating room were measured noting an average, peaks, maximums, minimums, and concurrent activities. The ability of the anesthesia provider to hear monitor tones and machine alarms, also was studied during perceived “high noise” episodes.

Purpose

The main purpose of this study was to measure and describe levels of noise in a modern day OR. Correlations of measured noise levels and the ability of an anesthesia provider to hear monitor tones and alarms cannot be undertaken until actual noise levels are measured and described. Future studies could use information from this study to compare noise levels in the OR with the ability of the CRNA to hear monitor tones and alarms. Additionally, this information could provide the basis for studying the effects of noise levels on the cognition and vigilance of CRNAs.

A second purpose of this study was to compare noise levels measured during this study to the current standards for exposure to noise developed by NIOSH (1998). The Occupational Safety and Health Administration (OSHA) adopted the recommendations

of NIOSH and currently governs safe noise levels in the work place (NIOSH, 1998). A correlation between OSHA standards and the actual level of noise in an operating room was made.

A third purpose of this study was to determine what specific, significant noise generating events could be identified in the OR. Noise levels do not remain constant over the course of an operation. There may be only specific times and events that inhibit the ability of the CRNA to hear monitor tones and alarms. Identifying specific noise generating times and events could help narrow future investigations to target them.

Research Questions

The primary question in this study was: What is the level of noise in an operating room? A second question was: How do levels of noise in the OR compare to NIOSH standards? A third question was: What specific times and events are associated with significant increases in noise levels in the operating room?

Conceptual/Theoretical Framework

Vigilance is important to all aspects of nursing, especially when caring for patients vulnerable to complications, as they are in the OR. Central to the study of vigilance is the Signal Detection Theory where performance is measured in terms of detection of a signal and the response criteria used by the observer in responding to the signal (Edsall, 1993). According to the theory, decrement in vigilance over time comes from a shift of attention to a more conservative response. The signal is heard but not listened to. This lack of response may be due to distraction. There are many environmental and human factors that can lead to distraction in the OR, and noise is definitely one (Weinger & Englund,

1990). Our study seeks to gain knowledge of the extent that signal detection by the CRNA is affected by noise in the OR.

Davies and Jones (1985) described certain characteristics of tasks that make individuals more susceptible to the detrimental effects of noise. Among these are: (a) The difficulty of the task (more difficult tasks are more susceptible to disruption by noise), (b) The demands on long-continued attention (especially when the measures of performance are chosen to be sensitive to periods of momentary inefficiency), and (c) The opportunity to do the task in several different ways (recent studies have shown that the effect of the noise is the deployment of various strategies and the range of such strategies will in part dictate the range of operation open to the individual).

A number of situational variables also play a role in determining the degree of disruption of efficiency. Factors such as the degree of perceived control of the noise and temporary or enduring beliefs about the effects of noise on efficiency can serve to modulate noise effects. Kam et al. (1994) found that the perception of lack of control of the noise resulted in an increase in annoyance of several anesthesia providers, which subsequently decreased their efficiency and performance.

Weinger and Englund (1990) suggested that the effects of noise on performance depended upon the type of noise and the task being performed. Difficult tasks that require high levels of perception processing are adversely affected by noise (Murthy et al., 1995). The CRNA's job is one that requires long-continued attention, processing of much data, and performance of difficult tasks. The levels of noise in the operating room could be a participating factor in the efficiency and performance of these tasks.

Definitions

The following terms were used during the study and are provided for clarification.

Noise

Conceptual. “Any unwanted or undesirable sound, which is subjectively annoying or disrupts performance and is physiologically and psychologically stressful” (Kam et al., 1994, p.982).

Operational. Noise was measured using the Larson Davis-820 (Larson-Davis, Provo, Utah) integrated sound level meter (LD-820). Events associated with a high level of noise, represented by difficulty or inability to hear monitor tones, will be documented on the data collection sheet (see Appendix A).

Decibel (dB)

Conceptual. A logarithmic scale expressing the ratio of a sound pressure to a reference level. An increase of 10 dB is perceived as a sound twice as loud. “dB(A)” is a frequency-weighted scale filtering out frequencies below 1 kHz. Frequency, which determines pitch, is measured by the number of cycles per second (Hz). The human ear is able to perceive sounds within a frequency range of 20 to 20,000 Hz, and most sounds in everyday life are between 60 and 6000 Hz (Kam et al., 1994), the range where most speech information resides (United States Environmental Protection Agency [U. S. EPA], 1974).

Operational. Noise measured by the LD-820 integrated sound level meter was measured in A-weighted decibels.

Operating Room

Conceptual. A room in a health care facility in which surgical procedures that require anesthesia were performed.

Operational. Noise was measured, with an LD-820, in an orthopedic OR during orthopedic surgical procedures.

Associated Events

Conceptual. Occurrence connected with the production of noise

Operational. Events associated with a high level of noise, represented by difficulty or inability to hear monitor tones, was documented on the data collection sheet (see Appendix A).

Assumptions

The following were the assumptions associated with this study:

1. Excessive noise in the OR is undesirable.
2. Noise can be measured accurately
3. Noise in the OR is controllable to a certain degree.

Limitations

Limitations of the study included:

1. Data may not apply to other ORs. Operating rooms differ in size, layout, materials used in construction.
2. Data may not apply to other operating procedures. This was due to the use of different types of electrical equipment during different procedures, which produced different levels of noise.

CHAPTER II: REVIEW OF LITERATURE

Introduction

Many factors can distract the anesthesia provider in the OR, all of which can lead to human error in completing key tasks related to patient care, and ultimately to unfavorable patient outcomes. These include factors such as training and experience, workplace constraints (as in the size of the field of view the anesthesia provider has of the patient), fatigue, and sleep deprivation. Boredom, stress, state of the anesthesia provider's health, substance abuse, and task factors can also add to distraction. Environmental factors such as room temperature and humidity, exposure to toxic vapors, ambient lighting, interpersonal and team factors, equipment used and noise level can also lead to unfavorable patient outcomes when not ideal (Weinger & Englund, 1990).

In this literature review an examination of research relative to operating room noise and anesthesia providers will be presented. Issues in the literature pertaining to the effect of noise on the body, communication, cognition and the performance of complex psychomotor tasks; the role equipment alarms play in contributing to the noise and their effect on job performance will be described. Measurements of the amount of noise in the OR environment and the degree to which anesthesia providers can detect equipment alarms despite the noise will also be examined.

In a search of Medline (1970-1999), little research could be found to describe the levels of noise in the OR or the difficulty anesthesia providers have in hearing audible monitoring tones and alarms. The most recent literature that actually measured noise in ORs in the United States was published over 25 years ago (Cromer, 1974). Limited research published since that time focuses on how noise affects cognition (Kam et al.,

1994; Murthy et al, 1995), communication (Hodge & Thompson, 1990; Weinger & Englund, 1990) and efficiency and task performance (Davies & Jones, 1985; Eschenbrenner, 1971). Most studies focus on the performance of tasks and do not include data on the work environment. The research studies also omit the subjective aspects of an individual's culture and sensitivities. Comparisons between previously measured noise levels and the inability of anesthesia providers to hear monitor tones and alarms while in the operating room have not been made.

Operating Room Susceptibility to Noise

The literature defines noise in many ways. The simplest definition is any unwanted sound (Murthy et al., 1995). Shapiro and Berland (1972) go a step further to define noise as unwanted sound that causes annoyance and a decrease in efficiency. A more encompassing definition includes the subjective aspects of cultural and social factors and individual sensitivities. These must also be combined with the individual's sense of control over a situation and whether or not the noise was sudden or expected (Kam et al., 1994). Hodge and Thompson (1990) note that not only the type of noise (predictable or controllable) plays a role, but also the level of noise and the complexity of the task to be performed.

Although noise levels have been recognized as harmful to man for at least 2,500 years, and in spite of technological advances, noise levels in hospitals have increased to an extent that they are potentially harmful to both patients and personnel (Kam et al., 1994). ORs remain as susceptible to noise pollution as many other working environments. Staff and patients are exposed to a multiplicity of sounds in the OR such as those produced by patient monitoring devices and alarms, suction machines, orthopedic drills, and other

mechanical and pneumatic tools. Staff communication, whether necessary or unnecessary, adds to the clatter and comes in the form of intercoms, ringing telephones, page devices, and conversation. This cacophony is often heightened by noise from adjacent scrub-up areas, instrument rooms and sterilizers (Hodge & Thompson, 1990).

Physiologic Aspects of Noise

Despite the subjective nature of the definition of noise, many objective effects of noise can be demonstrated physiologically. A majority of the physiologic responses described by Selye stem from the stress response, which stimulates our sympathetic nervous system, leading to increased heart rate and blood pressure as cited in Kam et al. (1994). Other aspects of the sympathetic response include peripheral vasoconstriction and dilation of the pupils (Shapiro & Berland, 1972). Sudden unexpected noise may cause a startle reaction impairing concentration and vigilance (Kam et al., 1994). The most serious effect of noise in the OR is the impairment of communication (Hodge & Thompson, 1990). The impaired communication due to extensive background noise can lead to the Lombard effect in which speech is raised to counteract the noise. Masking of auditory signals can also occur if the signal-to-noise ratio is too low (Kam et al., 1994). The escalation of voices and alarm sounds in an attempt to improve aspects of communication can add psychological stress to physiological stress. According to Kam et al., the psychological reaction of annoyance may result from both the noise and impaired communication. This annoyance reaction can lead to decreasing accuracy and ability to perform complex tasks.

Effects of Noise on Communication in the Operating Room

In the 1990 study by Hodge and Thompson, cited above, researchers in Australia measured noise levels in the OR during a radical neck dissection. The procedure was described as a “typical major surgical procedure.” The measurement took place during the entire procedure. Noise was measured by two sound level monitors: a Bruel and Kjaer 2209 device, and a Copenhagen device. Audio cassettes recorded the measurements using a PCm-F1 digital audio processor and a SL-F1 video cassette recorder. The microphone was placed over the surgical field at the level of the surgeon’s ears. Additionally, specific surgical equipment was measured individually to determine the maximum sound levels produced during surgery. For comparison, the authors cited A-weighted decibel [dB(A)] levels of commonly occurring events. For example, the rustle of leaves is measured at 10 dB(A), light traffic at 50 dB(A), a motorcycle at eight meters at 90 dB(A), and a jet aircraft at 140 dB(A). Hodge and Thompson derived these ratings from Physics for the Life Sciences (Cromer, 1974).

During the study, background noise was measured at 13 dB(A) before any activity in the OR began. In the absence of any single, noise generating event, Hodge and Thompson (1990) reported sound levels of less than 51 dB(A). This is close to the 50 dB(A) reported for light traffic. The lowest single event measured was the inflation of the calf compression machine at 52 dB(A). Alarm noise measurements ranged from 74 to 80 dB(A). Suctioning of the pharynx by the anesthesia provider was measured at 75-80 dB(A). Gas escaping from an anesthetic gas cylinder while being replaced was measured at 103 dB(A). The highest measurement obtained for a specific event during surgery was at 108 dB(A), when a steel bowl fell to the floor. Additional findings were that a sudden,

unexpected increase of 30 dB(A) (i.e. dropping surgical instruments on the floor) was likely to cause a “startle response”.

Hodge and Thompson (1990) concluded from their study that normal communication at less than one meter was impaired at levels above 68 dB(A). A second conclusion was that noise should be a consideration when designing ORs. A final conclusion was that monitors and alarms used by anesthesia providers should produce signals that will be recognized by the provider, but should not create a distraction to other staff in the OR. No limitations were addressed in this study. Kam et al. (1994) published a review of this study, as well as a synthesis of the current literature at that time. Kam et al. concluded that current levels of noise in the OR impaired complex tasking, and interfered with communication.

In an article, Weinger and Englund (1990) discussed factors that affect “anesthetic vigilance.” The authors proposed that factors that influence the anesthesia provider’s ability to maintain vigilance were poorly understood. They suggested that little research had been done to increase this understanding. This collaborative review was the combined opinion of an assistant professor for the department of anesthesiology at the University of California, and the director of the Performance Enhancement Laboratory, Ergonomics Department, Naval Health Research Center, San Diego, California. Noise, among other factors, was identified as detrimentally affecting the vigilance of the anesthesia provider. Two major conclusions of this study related to noise. First, Weinger and Englund concluded that current noise levels in the OR affect communication, and second, that loud noises, such as those in ORs, were very disruptive and may impair the “auditory vigilance” of the anesthesia provider.

Effects of Noise in the Operating Room on Cognition

A more recent study published pertaining to how noise affects the anesthesia provider was completed in Canada by Murthy et al. (1995). The purpose of this study was to compare cognitive function among anesthesia providers with OR noise. The authors began their research by measuring the noise level in various ORs, using a Bruel and Kjaer type 2230 sound level meter. The meter was placed approximately 25 cm from the anesthesia provider with the microphone at the same level as the provider's ears. Noise levels were measured for 15 minutes while the OR was being prepared for patients. Noise indices were then calculated deriving the lowest, highest, and average levels of noise. Five OR environments were identified as having the highest levels of noise: orthopedic surgery, general surgery, cardiothoracic surgery, emergency operations, and neurosurgery. These environments were then studied more intently. Noise levels were measured in three test periods, over three to five hours, for each OR environment. The first test period covered the preparation period and initial administration of anesthesia to the patient (anesthetic induction). The second measurement was taken during the actual surgical intervention (anesthetic maintenance). The third measurement occurred when the patient was being awakened from anesthesia (anesthetic emergence), including extubation of the trachea. Audiocassettes recorded these measurements.

A convenience sample of 20 anesthesia residents, 15 male and five female, volunteered to participate in the next phase of the study. Exclusion criterion was any known hearing impairment. The subjects were placed, individually, in acoustically treated rooms in the audiology department of the institution. Cognitive tests were administered without noise. One week later the subjects were retested, using the same

cognitive tests while being exposed to the prerecorded noise on the audiocassette tape. The second series of tests were given 10 minutes after noise exposure began. Noise levels were monitored 25 cm from the subject's ears, with the same type of sound monitor used in the operating rooms. Results showed a deterioration in "mental efficiency" and "short term memory." Mental efficiency was measured with two tests. The average drop between pre- and post-test scores was 6.55 and 8.95 ($p < .05$). Short-term memory was assessed using the Benton Visual Retention test. The average drop between pre- and post-test scores was 3.75 ($p < .05$). The conclusion drawn by the authors was that there was a reduction in mental efficiency and short term memory with exposure to levels of noise that were present in ORs. The major limitation, identified by the authors, was that the study was performed in an artificial environment and not in the OR (Murthy et al., 1995).

Effects of Noise on Psychomotor Task Performance

Recent research has been conducted on factors contributing to anesthetic errors and mishaps. Studies thus far indicate that a large portion of the anesthesia provider's job involves complex vigilance and monitoring tasks. The act of vigilance has been described as requiring a state of maximal physiologic and psychological readiness to react. Cooper and Newbower (1984), cited inadequate patient observation as a contributing factor to critical events associated with substantial negative patient outcomes. They reported 70 critical incidents, of which 28 (40%) were due to "technical errors," 23 (33%) to "judgmental errors" and 16 (23%) to "monitoring or vigilance errors." In a study by Boyan and Keenan (1985), 75% of the intraoperative cardiac arrests observed appeared to be preventable. They concluded that preventable anesthetic mortality was a serious problem and human error was a major contributor to this mortality. Factors that influence

this state of readiness, and thereby affect the anesthesia provider's ability to sustain vigilance, are poorly understood (Weinger & Englund, 1990).

In a landmark study, Eschenbrenner (1971) evaluated the effects of noise on complex cognition. In an attempt to expand beyond the effects of continuous noise, the author studied the effects of aperiodic and periodic intermittent noise on "complex psychomotor tasks" among 24 male employees of McDonnell Douglas Aircraft Company. The subjects sat in a McDonnell Douglas Image Motion Compensation simulator, which duplicates what one would see out of a spacecraft orbiting over the earth at a 100 nautical mile altitude. They were required to maintain the earth on screen at a certain angle of view, with the use of a hand controller to compensate for aircraft simulated movement.

Four groups of six subjects each were randomly assigned to three experimental groups, and one control group. The three experimental groups were assigned different noise patterns. The first group heard continuous noise; group two heard intermittent, evenly spaced noise; and the third group heard intermittent, randomly spaced noise. The control group also wore headphones but no noise was generated during their trials. All subjects were given standardized instructions, and all subjects received two days of training on the Image Motion Compensation simulator that was used during the study. Each day of training included 25 trials, or passovers. On the third day the experimental variable, noise, was introduced to the subjects, and again for two successive days thereafter. Each experimental session entailed 20 trials. For each trial the subjects were placed in the Image Motion Compensation simulator. The simulator "duplicates an optical system in a 100 nautical mile earth orbit." The simulator uses a photograph rotated in such a manner as to simulate an orbital pass over a region of the earth's

surface. The simulator is equipped to mimic a spacecraft, to include rotation around two axes. Each simulated passover was 40 seconds in duration. A Lafayette Noise Generator fed noise into a Scott Steriophonic Amplifier and supplied noise to the subjects through a set of binaural earphones. Noise output was measured with a Bruel and Kjaer sound meter. Noise was produced at 50, 70, and 90 dB(A). The initiation of each passover was simultaneous to the beginning of the noise. In addition to noise intensity, noise patterning was varied according to the noise pattern assigned to each group. Noise patterning was performed using a Hewlett-Packard noise oscillator (Eschenbrenner, 1971).

The training trials were analyzed, and Eschenbrenner (1971) drew the conclusion that the subjects' skill levels were equivalent before introducing the experimental variable. After introduction of noise, the researcher measured the total time the image of the earth's surface was held within the designed criterion. A comparison of the control group and the continuous noise group was analyzed first. The control group stayed within the criterion, a mean of 195.50 seconds, and the continuous noise group averaged 161.07 seconds ($p < .01$). A mean of 155.60 seconds was found for the intermittent, evenly spaced group, and 135.87 seconds for the randomly spaced group ($p < .001$). Eschenbrenner concluded that all noise patterns in their study "produced significant decrements." A second conclusion was that the decrement varied relative to the intensity level and pattern of the noise. The aperiodic noise group exhibited the largest decrease, significantly different from the other two ($p < .01$). The evenly spaced, intermittent noise group performed better than the unevenly spaced, intermittent noise group. Significant differences also were found among the three intensity levels ($p < .01$) with performance deteriorating as noise increased.

A conclusion derived from the data was that predictable noise occurrences cause less impairment than unpredictable occurrences. There were no limitations, or exclusion criterion cited for this study (Eschenbrenner, 1971). One flaw in the study was the fact that the subjects were studied in a simulator and not their actual work environment. An exact correlation to OR noise may not be possible; however many alarms provide aperiodic high intensity sounds similar to those in flight simulation, which could play a role in anesthesia providers' performance and maintenance of vigilance.

The Effects of Alarms

Alarms are an important aspect of anesthesia care. Their purpose is to alert the provider when an unacceptable medical condition exists or when there is an equipment failure that can result in an unacceptable medical condition. The use of visual displays is not enough, as anesthesia providers are usually occupied by a number of other visual tasks in addition to the patient's monitor (Momtahan, Hetu, & Tansley, 1993).

Information in the literature pertaining to alarms is varied, and different authors propose different problems related to alarms. In one study, anesthesia providers reported spending too much time differentiating between auditory warnings and silencing them, which reduced time for more important tasks (Momtahan et al., 1993). The extensive time spent in attempting to differentiate between alarms is due to the fact that the tones of many alarms are acoustically similar. These similar tones also may cause some alarms of lesser importance to mask the sounds of more important alarms, which may be warning of a life-threatening situation (Meredith & Edworthy, 1995; Samuels, 1986). Auditory alarms that are continuous are difficult to remember and are more likely to mask other signals. Intermittent alarms are unlikely to mask continuously sounding alarms. Many

alarms are masked by noises produced by other equipment in the OR (Momtahan et al., 1993).

Many anesthesia providers simply choose to turn alarms off because they feel they are too loud, distracting, and numerous. The ability for an individual to remember the significance and meaning of a large number of alarms has also been questioned. In a study by Momtahan et al. (1993), anesthesia providers were presented with 26 auditory alarms and asked to identify them and their meaning of urgency. An alarm identification rate of only 40% was noted; however, frequency of alarm identification in relation to alarm importance was significant ($p < .05$). These findings suggest that even though the meaning of all of the alarms may not have been remembered, the more important ones were identified. Suggestions related to the improvement of alarms that resulted from this study included a decrease in the number of alarms, use of distinctive sounds from different alarms, and a specific level of urgency associated with each alarm.

Another reason anesthesia providers choose to turn alarms off has been the amount of false alarms received (Weinger & Englund, 1990). In a study of 50 patients receiving elective surgery, a mean of 10 alarms sounded per surgery, with a frequency of one alarm every 4.5 minutes. Seventy five percent of the alarms that sounded were noted to be spurious and only 3% actually indicated risk to the patient (Kestin, Miller, & Lockhart, 1988).

Noise Measurements in the Operating Room

Measuring the noise in the OR environment has allowed researchers to describe the actual contribution of alarms and other specific factors. Unfortunately, only a few researchers have actually performed these measurements. During a radical neck

dissection sounds were measured in the OR with a microphone placed centrally over the operating field and the level of the surgeons ear. The sounds ranged as high as 108 dB(A) from a stainless steel bowl falling to the floor to as low as 52 dB(A) for an intermittent calf compression machine inflating. An oxygen supply alarm measuring 80 dB(A) and an electrocardiogram alarm measuring 75 dB(A) also were among the range of sounds (Hodge & Thompson, 1990). The finding that the sounds of alarms range in the middle of all the noise measured brings up the question of the anesthesia provider's ability to hear them amidst the many other louder contributors. Measuring the levels of noise closer to the anesthesia provider's work area would better demonstrate specific noises heard least or best by the anesthesia provider.

In a study by Shapiro and Berland (1972) sound was recorded through a microphone located midway between the surgeon's ear and the patient's ear during a combined cholecystomy and tubal ligation in a healthy woman in her mid 30s. The authors equated their measurements of noise levels to that of a freeway or a blender running in a kitchen. No alarm levels were noted in their study, and the loudest sound was opening a package of rubber gloves measured at 86 dB(A). The lowest sounds were various suction tubes, which measured at 55 dB(A). They found that the noise levels in the OR came close to the maximum permissible noise exposure (per eight hours) of 90 dB(A) set forth by the United States Occupational Safety and Health Administration at that time. This study like the previous study concentrated on noise around the patient and surgeon and not the anesthesia provider. Both studies also made no mention of questioning the anesthesia providers about their ability to hear specific alarms and monitoring devices.

Summary

Administration of anesthesia is a task where even momentary lapses of concentration and vigilance can result in serious consequences to the patient. Noise has many physiological and psychological effects on the human body, and may impact an individual's ability to concentrate and perform tasks. Various alarms and levels of noise are present in the OR setting. A review of the literature suggests that high noise levels and similar tones of alarms limit an anesthesia provider's ability to effectively administer anesthesia. It also suggests that the number of alarms contribute to the noise level and decrease the anesthesia provider's ability to remain focused on the care of the patient. More research is needed, however, to measure noise and alarm levels specifically at the location of the anesthesia provider. These studies include attempts to find answers to questions regarding the anesthesia provider's ability to hear alarms and monitoring devices and how, if at all, an inability to hear alarms and monitoring devices affects an anesthesia provider's vigilance.

CRNA vigilance is crucial to the well-being of patients, and if the cause of the noise can be identified and corrected, CRNAs in the future may be able to administer anesthesia in a much safer environment and possibly improve patient outcomes.

CHAPTER III: METHODOLOGY

Introduction

The main purpose of this study was to measure and describe levels of noise in the modern day OR environment. In this chapter, the research methods used in this descriptive study will be outlined. The research design, sample, and measurement of noise will be addressed. Instrumentation used to make preliminary correlations between noise levels and monitor tones also will be described.

Sample and Setting

The study took place in an orthopedic OR of a 90-bed military hospital in the Midwest. Other surgical procedures performed in this hospital included adult and pediatric general, neurologic, gynecologic, cardiac, ear, nose and throat surgeries. On average, there were 70 surgeries performed per week, within eight ORs.

Rooms in which orthopedic procedures are performed have been documented to have among the highest levels of noise of any OR (Murthy et al., 1995). Subsequently, a convenience sample of one orthopedic OR was chosen. The dimensions of the orthopedic OR are 29 feet 8 inches long, by 22 feet 8 inches wide, with a ceiling height of 9 feet 6 inches.

Measurements

The study used a prospective, non-experimental design. The variable noise was measured using a Larson-Davis 820 Integrated Sound Level Meter (Larson Davis, Provo, Utah). Officers from the Aural Displays and Bioacoustics Branch of the military base were consulted regarding the reliability and validity of the LD 820.

The establishment of inter-rater reliability related to ability to hear the pulse oximeter monitor tone was completed in an anesthesia simulator lab prior to the study. The pulse oximeter monitor tone in the lab was set at an audible level comparable to the level in the OR to be studied. A cassette recorder was played at different levels to simulate different levels of noise in the OR. The difficulty in the ability to hear the pulse oximeter monitor tone at the different music levels was compared and agreed upon by the three providers (see Appendix B).

Research Design and Procedures

Noise measurements were obtained for a four-week period, with measurements taken Monday through Friday each of those weeks. It was anticipated between 25 to 50 orthopedic procedures would take place in the assigned room within this period. Noise was measured continuously from the time of initial setup of the room by OR staff, to completion of the last procedure of the day.

The LD 820 was placed on the anesthesia machine and a microphone was stretched to hang from the ceiling near the head of the OR table. The microphone was hung 6 feet 6 inches from the floor, extending down approximately one foot above the CRNA's ear level. It was approximately 3 feet 10 inches from the machine and 9 feet 2 inches from the radio. Sound measurements at this level most closely represent levels heard by the CRNA.

Three specific providers were assigned to the orthopedic OR at two-week intervals to collect data. These providers remained alert to episodes in which the audible pulse oximeter monitor tone (set at 50% volume) was difficult to hear or could not be heard at

all due to the high levels of noise. Time, date and other specific factors surrounding these episodes were documented in an event log (see Appendix A).

The LD 820 was programmed to continuously measure sound (decibel levels) and provide summarized data at 10 minute increments. Both peak and average noise levels were identified, measured, analyzed, and compared to NIOSH (1998) standards. The sensor did not interfere with the anesthesia machine's operation or with patient care. In order to maintain instrument reliability and validity, all calibration, placement, removal, technical, and computer tasks were supervised by staff from the Aural Displays and Bioacoustics Branch.

It was anticipated that at times it would be difficult to hear the pulse oximeter monitor tone due to the high levels of noise. These high noise level episodes were documented in an event log (see Appendix A). Any specific events that were thought to contribute to excessive noise were also to be documented. At the end of four weeks, the event logs were to be analyzed. The time and date of the documented events which were perceived to cause high levels of noise were noted. Actual levels of noise at those specific times and dates were recorded by the LD 820 and specific events were to be correlated to the noise levels that exceeded standards.

Protection of Human Rights

The study was conducted after approval by Institution Review Boards at the academic and investigation locations. No individuals were recruited for participation in the study and patient care was not affected during the collection of data.

Data Analysis

Peak and average noise levels for each day were obtained from the LD 820 monitor log. Data were downloaded from the LD 820 into a laptop computer provided by the Bioacoustics Branch at the study site. The data were then submitted to the Bioacoustics Branch where they were transformed into a format suitable for data analysis. Peaks were compared to the specific noise generating events identified by the three providers. These levels in addition to minimum, maximum and other levels were summarized, analyzed and compared to NIOSH (1998) standards. Correlations between noise levels and the anesthesia provider's ability to hear the pulse oximeter monitor tone also were analyzed.

CHAPTER IV: ANALYSIS OF DATA

Introduction

In this chapter, an analysis of data gathered during the study will be discussed. An overview of the demographics and background will be presented followed by an analysis of the data as they relate to the research questions.

Demographics and Background Data

Data were gathered over a period of four weeks. Although the OR studied was typically used for orthopedic procedures, not all procedures in the study were orthopedic in nature. Surgical procedures were performed on thirteen days during the four-week study period. A total of 26 surgical procedures were performed, of these 21 were orthopedic cases. Fifteen cases were performed using general anesthesia (GETA); five using monitored anesthesia care with local anesthetic injection performed by the surgeon (local/mac); four using spinal anesthesia; and one using intravenous regional anesthesia (Bier block). One case was cancelled after the patient had been premedicated, brought into the OR, and attached to monitors. Table 1 summarizes the cases studied.

Operating Room Sound Levels

The LD 820 (Larson Davis, Provo, Utah) was the instrument used for measuring decibel levels. In this study, the LD 820 was programmed to continuously measure sound (decibel levels) and provide summarized data at 10-minute increments. The device was turned on before the first case of the day and ran continually until after the last case of the day was completed. Times between surgical procedures were identified and excluded from data analysis. Bioacoustics personnel generated minimum, maximum, peak, and Leq decibel levels in ten-minute increments from the data submitted.

Table 1

Study Results by procedure

Case	Procedure	Anesthesia	Leq	Min	Max	Peak	L90
1	Carpel tunnel release	Bier block	62.4	46.8	87.8	102.8	51.3
2	Inguinal hernia	GETA	66.0	51.9	89.2	110.2	55.5
3	Knee arthroscopy	GETA	67.3	52.8	90.7	111.4	56.2
4	Shoulder arthroscopy	GETA	64.5	52.6	86.0	106.5	57.2
5	Breast I & D	local/Mac	64.8	51.8	87.8	111.0	56.1
6	Hand cystectomy	local/Mac	60.1	47.0	80.4	105.4	50.7
7	ACL repair	GETA	65.9	54.0	85.8	105.5	57.6
8	Carpel tunnel release	local/Mac	63.9	49.0	86.4	100.8	52.6
9	Shoulder acromioplasty	GETA	66.4	52.6	86.8	107.9	57.0
10	Shoulder acromioplasty	GETA	68.1	53.5	92.1	115.9	58.0
11	Breast Augmentation	GETA	63.3	53.3	85.1	110.9	55.8
12	Shoulder acromioplasty	GETA	63.3	53.8	85.0	110.4	56.7
13	Cyst excision	GETA	65.1	49.5	87.3	110.6	54.6
14	Knee arthroscopy	Spinal	64.9	49.9	85.7	106.8	55.1
15	Carpel tunnel release	local/mac	62.1	48.1	83.8	102.7	53.7
16	ACL repair	GETA	65.4	54.6	91.3	132.7	58.1
17	Shoulder acromioplasty	GETA	66.9	52.5	94.5	121.4	58.6
18	Knee arthroscopy	Spinal	69.0	50.7	87.4	113.6	56.6
19	Knee arthroscopy	Spinal	69.4	53.9	87.1	106.0	59.2
20	Knee arthroscopy	Spinal	66.6	51.6	89.1	107.1	58.0
21	Finger pinning	local/mac	67.1	50.8	86.1	101.8	56.6
22	Wrist pinning	GETA	64.6	52.2	85.5	107.0	56.2
23	Open shoulder	GETA	64.3	48.3	88.9	112.6	54.6
24	Cancelled (before induction)		66.8	50.6	95.0	117.2	53.9
25	Osteotomy	GETA	64.5	54.3	88.1	106.5	57.0
26	ACL repair	GETA	63.9	55.0	85.9	105.2	58.0

Note: Numerical data are dB(A) values.

The Leq is the average amount of energy generated by the movement of sound waves through the air and expressed numerically in a decibel format. For our purposes, the Leq can be considered the logarithmic average of all decibel levels measured within each 10

minute increment. Peak decibel levels are defined as the highest A weighted decibel level reached during each ten minute increment. This time could be as small as a fraction of a second. The peak differs from the maximum in that the maximum decibel level reported for each ten minute increment represents a substantially longer time frame relative to the peak. For example, the peak for a ten minute interval may represent only 0.005 seconds, whereas the maximum may represent a time frame of several seconds. The minimum, like the maximum, represents a time frame of greater than a split-second.

Data obtained from the Bioacoustics Branch included L levels, such as Leq, L1, L5, L10, L50, L90, and L99. These values represented the percentage of time in which the sound level was at least the expressed decibel. An example is the L90 which represents a decibel level that was maintained for 90 percent of the ten minute increment, or nine out of ten minutes. Surgical procedure number one (see Table 1) had an L90 of 51.3 dB(A). This means that for 90 percent of the procedure the decibel level was at least 51.3 dB(A). The L90 for each surgical procedure was determined by calculating the logarithmic average of all the L90s measured during that procedure. The minimum, maximum, peak, and Leq for each surgical procedure were determined using the same technique and is listed in table 1. Logarithmic calculations are necessary since decibels are expressed as logarithmic values.

In consulting with bioacoustics scientists, it was determined that the minimum, maximum, Leq, and L90 were significant for this study. The peak was not felt to be significant because it represents only a small fraction of the time measured and would not likely inhibit the auditory vigilance of the anesthesia provider. The maximum, and the minimum, represents an amount of time that could last for many seconds. The maximum

would therefore be more likely to represent noise levels that would interfere with the anesthesia provider's ability to hear monitor tones and alarms. The L90 value indicates that 90 percent of the procedure time the noise levels were at least the expressed L90 decibel level. Thus, for example, the L90 would represent 162 minutes of a procedure lasting 180 minutes. The remaining eighteen minutes would represent an average time frame of one minute of each ten-minute interval, or six seconds of each one minute interval. The L99 would represent 178 minutes of a 180-minute procedure. The remaining two minutes would represent an average of eighteen seconds for each ten-minute increment, or 0.6 seconds of each minute. A sound lasting six seconds is more likely to interfere with the anesthesia provider's ability to hear monitor tones and alarms than a sound lasting 0.6 seconds. If a sound above the L90 occurred only once in five minutes it would cover a 30 second time frame, whereas the L99 would cover only three seconds of time. Subsequently, the L90 would represent noise levels more likely to interfere with the anesthesia providers' auditory vigilance.

Table 1 shows that the maximum decibels for all the surgical procedures ranged from 80.4 dB(A) measured during a hand cystectomy, to 95.0 dB(A) that occurred during the procedure that was cancelled before induction. Minimum decibel levels ranged from 46.8 dB(A) measured during a carpal tunnel release, to 55.0 dB(A) measured during an ACL repair. The Leq range had a low value of 60.1 dB(A) that occurred during the hand cystectomy and a high value of 69.4 dB(A) measured during a knee arthroscopy. The L90 ranged from 50.7 dB(A) measured during the hand cystectomy to 59.2 dB(A) measured during a knee arthroscopy. The low values for the maximum, Leq, and L90 were all measured during the same surgical procedure. The procedure was a hand

cystectomy performed under local/mac anesthesia. The high values for the Leq and L90 were both measured during the same knee arthroscopy. Figure 1 plots the values of the minimum, L90, Leq, maximum, and peak for all procedures measured in the study.

Baseline decibel levels of monitor tones and alarms were measured during a time when there was no surgical procedures or other activities being performed in the operating room studied. The ventilator on the anesthesia machine had alarms for low oxygen, high pressure or volume, and apnea. The low oxygen alarm was measured at 76 dB(A). The high pressure alarm, as well as the apnea alarm, was measured at 75 dB(A). The monitor is a Marquette Solar 7000 series. Monitor tones and alarms have an adjustable volume and were measured with the volume at 20 percent, 50 percent, and 100 percent. The pulse oximeter tone was measured at 51 dB(A) at 20 percent volume, 55 dB(A) at 50 percent, and 65 dB(A) at 100 percent. The pulse oximeter alarm was measured at 52 dB(A) at 20 percent volume, 58 dB(A) at 50 percent, and 72 dB(A) at 100 percent. The typical radio volume determined by the researchers was measured with decibels generally in the sixties and a high level noted at 71 dB(A). The radio was positioned on a table behind where the anesthesia provider stands 9 feet, 2 inches from the LD820 microphone. This is typically where the radio is positioned in this OR.

NIOSH (1998) standards recommend that for a worker's safety the decibel level should not exceed 85 dB(A) for an eight hour work period. In this study the Leq had a maximum measured level of 69.4 dB(A) and the L90 had a maximum measured level of 59.2 dB(A). The maximum values ranged from 80.4 dB(A) to 95.0 dB(A). At times the maximum level may have exceeded 85 dB(A) for several seconds but the average decibel level was substantially below the NIOSH (1998) standard for an eight hour period.

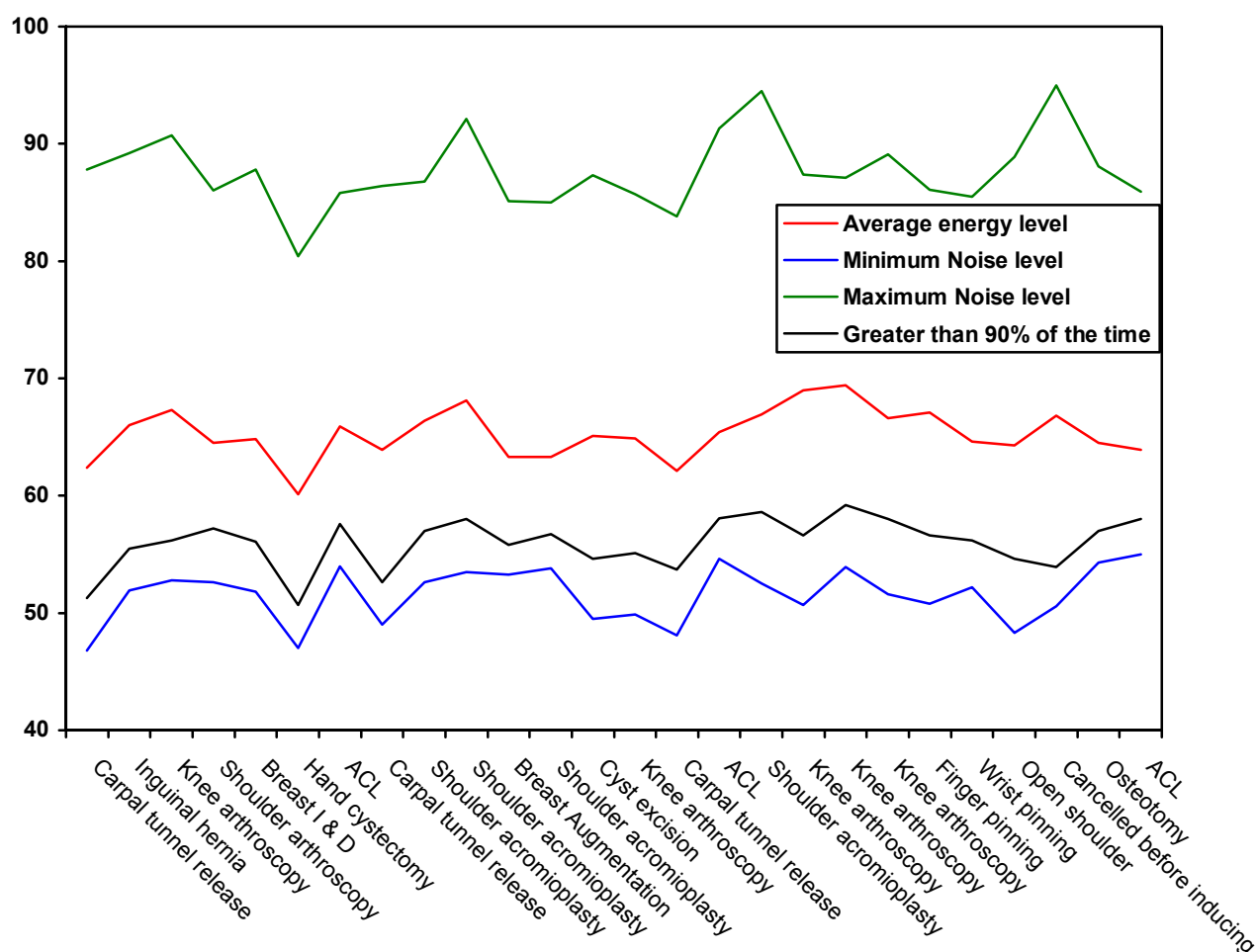


Figure 1. Decibel levels by procedure.

In addition to the eight hour standard of 85 dB(A), NIOSH (1998) has established exposure limits based on decibel levels and times of exposure (see Table 2) Although one cannot conclusively state by analyzing the data in table 1 that at no time was the anesthesia provider exposed to sounds levels exceeding NIOSH standards, based on decibel level and duration of exposure, it appears that is the case. For example, employee exposure to 90 dB(A) should be less than 2 hours, 31 minutes. The maximum decibel levels (in Table 1) for case numbers 3, 10, 16, 17, and 24 exceed 90 dB(A). Case numbers 3 and 24 lasted less than the 2 hour, 31 minute standard. Case numbers 10, 16, and 17 were longer than 2 hours, 31 minutes. Case number 16, an ACL repair, was the

longest, lasting 5 hours, 25 minutes. However, the Leqs for all five surgical procedures were less than 70 dB(A), indicating that on average the decibel level during the procedure was less than 70 dB(A). It would therefore have been impossible to exceed 90 dB(A) for more than 2 hours, 31 minutes. Measured peaks during the surgical procedures were so brief that it is very improbable these higher decibel levels would exceed NIOSH (1998) standards. An exception to this statement may be case number 16, an ACL repair. The peak, which represents a fraction of a second, was 132.7 dB(A). Table 2 indicates that exposure to decibel levels of 130 to 140 dB(A) should not exceed a duration of less than one second. The peaks were also so brief that they most likely did not interfere with the anesthesia providers' ability to hear monitor tones and alarms.

Significant increases in the level of noise that made it difficult for the anesthesia provider to hear the monitor tones were noted 12 times over the four-week period of study. Seven of the twelve times the anesthesia provider noted that monitor tones were poorly heard. The decibel level ranged from 58.7 dB(A) to 63.5 dB(A). The five times when the anesthesia provider could not hear the monitor tones at all had a decibel range from 59.5 dB(A) to 64.2 dB(A). The events that occurred when it was difficult to hear included the radio being turned on or up, conversation in the room, a surgical scope falling to the floor, and use of a surgical saw. The conversation included both that necessary for the progression of the procedure and that not necessary for the progression of the procedure.

Table 2

Standards for exposure level durations by NIOSH

Combinations of noise exposure levels and durations that no worker exposure shall equal or exceed							
Exposure level, <i>L</i> (dBA)	Duration, <i>T</i>			Exposure level, <i>L</i> (dBA)	Duration, <i>T</i>		
	Hours	Minutes	Seconds		Hours	Minutes	Seconds
80	25	24	—	106	—	3	45
81	20	10	—	107	—	2	59
82	16	—	—	108	—	2	22
83	12	42	—	109	—	1	53
84	10	5	—	110	—	1	29
85	8	—	—	111	—	1	11
86	6	21	—	112	—	—	56
87	5	2	—	113	—	—	45
88	4	—	—	114	—	—	35
89	3	10	—	115	—	—	28
90	2	31	—	116	—	—	22
91	2	—	—	117	—	—	18
92	1	35	—	118	—	—	14
93	1	16	—	119	—	—	11
94	1	—	—	120	—	—	9
95	—	47	37	121	—	—	7
96	—	37	48	122	—	—	6
97	—	30	—	123	—	—	4
98	—	23	49	124	—	—	3
99	—	18	59	125	—	—	3
100	—	15	—	126	—	—	2
101	—	11	54	127	—	—	1
102	—	9	27	128	—	—	1
103	—	7	30	129	—	—	1
104	—	5	57	130-140	—	—	<1
105	—	4	43	—	—	—	—

Source: National Institute of Occupational Safety and Health, 1998.

The events that were associated with not hearing the monitor tone included the surgical team speaking in loud voices, a surgical drill in use, and the radio being turned on. The pulse oximeter tone volume was set at 50 percent for all procedures in the study.

It should be noted that the use of electrical surgical instruments, conversation in the room, and having the radio on occurred on many occasions where the anesthesia provider did not report any difficulty in hearing monitor tones and alarms.

Summary

This chapter has presented the findings obtained from the LD 820 sound measurement device during a four-week study period in an orthopedic OR. Noise levels during 26 surgeries were analyzed. Decibel levels were presented and discussed resolving the primary research question of what is the level of noise in the operating room studied. Measured decibel levels were compared to NIOSH (1998) standards. The noise levels did not exceed the NIOSH standard of an average of 85 dB(A) for an eight hour time period. Additionally, it is possible, but unlikely, that the anesthesia provider was exposed to noise levels exceeding NIOSH standards at any time while performing anesthesia in the operating room. The ACL repair that had a peak of greater than 130 dB(a) may have exceeded NIOSH standards.

Specific times and events associated with perceived difficulty in hearing monitoring tones and alarms were identified. The decibel levels during those times were not significantly higher than times where there were no perceived difficulties in hearing monitor tones and alarms. In fact, there were recorded times in which monitor tones and alarms could adequately be heard and the decibel level exceeded the decibel level of the times in which there was perceived difficulty in hearing. Subsequently, specific decibel levels could not be identified as causing a deficit in auditory vigilance. Other factors, not included in this study, may play a more important role in the anesthesia providers' ability to maintain auditory vigilance.

CHAPTER V: CONCLUSIONS

In this final chapter, findings are synthesized and conclusions are drawn from this study. The theoretical framework discussed previously is applied and recommendations for CRNA practice and future study are made.

Research Question #1

The first research question of this study was: What is the level of noise in an operating room? Noise levels in an orthopedic OR were measured with an LD 820 sound level meter measuring device. The sensor was located approximately 1 1/2 feet overhead of the CRNA and measured room noise levels continuously from the start to the end of the OR day. Only noise levels measured from the beginning to the end of actual surgery times were included in the study. Noise levels that occurred before and after surgeries were not included since during those times, the CRNA is not monitoring patient alarms.

Overall, the average OR noise level, (mean Leq) was 65.8 dB(A). The minimum noise levels ranged from 46.8 to 55.0 dB(A). The maximum noise levels ranged from 83.8 to 95.0 dB(A) and peak levels from 100.8 to 132.7 dB(A). With the exception of noise generated due to a canceled procedure, a shoulder acromioplasty surgery measured the highest maximum with a level of 94.5 dB(A). A carpal tunnel release surgery measured the lowest minimum with a level of 46.8 dB(A).

The decibel level of monitor tones and alarms were measured during a time when there were no surgical procedures being performed. Monitor tones and alarms had an adjustable volume and were measured with the volume at 20 percent, 50 percent, and 100 percent. The pulse oximeter tone at twenty and fifty percent volume was lower (51 and 55dB(A), respectively) during a time of no surgery than the mean minimum noise level in

the room during surgery (56.2db(A)). The pulse oximeter alarm was lower at 20 percent volume (52 db(A)) during a time of no surgery than the mean minimum noise level during surgery.

Research Question #2

The second research question was: How do levels of noise in the OR compare to NIOSH standards? NIOSH (1998) recommends that a worker's eight-hour total weight average should not exceed 85 dB(A). This recommendation was established placed in order to protect workers from excessive noise in the workplace that can cause hearing loss. Although it is impossible to present conclusive evidence using the LD 820 set to present data at 10 minute intervals, it appears that the anesthesia providers were not exposed at any time to decibel levels exceeding NIOSH standards, based on exposure levels and duration as described in Table 2. Clearly, with an average decibel level / mean Leq of 65.8 dB(A), noise exposure levels fall within the recommended eight-hour total weight average established by NIOSH.

Research Question #3

Vigilance is a central responsibility of the prudent CRNA. The Signal Detection Theory states that decrement in vigilance over time may be due to distraction of the observer to the signal (Edsall, 1993). For this reason, the study looked at a third research question: What specific times and events are associated with significant increases in noise levels in the OR? Specific times and events associated with perceived difficulty in hearing monitoring tones and alarms were identified and documented on the Noise Event Log (Appendix A). A correlation was made with the times of those events and the actual sound decibel level that was recorded at that time. The decibel levels measured during

those times were not significantly higher than times where there was no perceived difficulty in hearing monitor tones and alarms. There were recorded times in which monitor tones and alarms could adequately be heard, and the decibel level exceeded the decibel level of the times in which there was perceived difficulty in hearing. Specific noise levels measured in decibels did not correlate well with the anesthesia provider's ability or inability to hear monitor tones or alarms.

Recommendations

During this study, it was discovered that there may be other aspects of noise that may contribute to the inability of a CRNA to hear patient alarms in the OR in addition to decibel levels. Two noises may have the same number of decibels, but different pitch frequencies. One may still be able to hear an alarm ringing at a high frequency over the noise of an orthopedic drill vibrating at a low frequency, even though they share the same decibel rating. One noise that may have a low decibel rating with a high frequency may be heard over another noise with a high decibel and low frequency. We recommend that future studies address the question: What are the frequencies of OR noise-contributing events and how do they compare to the frequency of the pulse oximeter alarm? It would be beneficial to also compare frequencies of OR noise in relationship to hearing other important anesthetic related alarms, and how do the frequencies affect the anesthesia provider's ability to recognize these alarms.

Further recommendations for future study questions include: (a) How do OR noise levels affect the CRNA's efficiency of task performance? (b) What are the noise levels and frequencies in ORs of other institutions, among orthopedic cases and other specialties. (c)

A more in depth look at what specific noises do CRNAs associate with a decrement in vigilance?

Summary

The evolution of medicine has brought about many welcome advances in modern healthcare technology. With every change comes a higher expectation of patient care and safety. Few would argue against the fact that patient care and safety is of utmost importance to the CRNA. Advances in technology have undoubtedly contributed to the successful administration of a multitude of anesthetics.

Patient monitoring during anesthesia improves patient outcome by increasing the anesthesia provider's awareness of actual and potential problems (Sinkovich & Kossick, 1997). Lack of vigilance has been reported to be responsible for up to 30% of major problems occurring during anesthesia (Cooper, Kitz, & Newbower, 1984). Even a momentary distraction can prevent recognition of the cessation of heart sounds for up to three minutes (Kay & Neal, 1986).

Identifying factors that play a role in decreasing an anesthetist's vigilance, may lead to improved practice and patient outcomes. In this study, the level of noise in a typical operating room was measured, and correlations between noise levels and anesthesia providers ability to hear critical patient monitors was described.

Noise levels were measured during 26 cases were not found to exceed NIOSH (1998) standards of 85db(A) for an eight-hour work day. In addition, specific noise levels did not correlate well with the anesthesia provider's ability or inability to hear monitor tones or alarms. These findings bring some insight about the actual levels of noise in the operating

room, as well as the measured levels of monitor tones and alarms. The impact of these levels on anesthesia providers' vigilance has yet to be examined by future studies.

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Appendix A

Noise Event Log		
1.	Date _____ Time _____ Room# _____ Procedure _____ Pulse Oximeter Tone Setting _____ Event Scale _____ 1= Pulse Oximeter monitor tone <u>heard adequately</u> 2= Pulse Oximeter monitor tone <u>poorly heard</u> 3= Pulse Oximeter monitor tone <u>not heard at all</u>	<input type="checkbox"/> Radio turned on <input type="checkbox"/> Ventilator in use <input type="checkbox"/> Conversation necessary for the progression of the procedure <input type="checkbox"/> Conversation not necessary for the progression of the procedure <input type="checkbox"/> Suction in use <input type="checkbox"/> Bovie in use <input type="checkbox"/> Bair Hugger <input type="checkbox"/> Other _____
2.	Date _____ Time _____ Room# _____ Procedure _____ Pulse Oximeter Tone Setting _____ Event Scale _____ 1= Pulse Oximeter monitor tone <u>heard adequately</u> 2= Pulse Oximeter monitor tone <u>poorly heard</u> 3= Pulse Oximeter monitor tone <u>not heard at all</u>	<input type="checkbox"/> Radio turned on <input type="checkbox"/> Ventilator in use <input type="checkbox"/> Conversation necessary for the progression of the procedure <input type="checkbox"/> Conversation not necessary for the progression of the procedure <input type="checkbox"/> Suction in use <input type="checkbox"/> Bovie in use <input type="checkbox"/> Bair Hugger <input type="checkbox"/> Other _____
3.	Date _____ Time _____ Room# _____ Procedure _____ Pulse Oximeter Tone Setting _____ Event Scale _____ 1= Pulse Oximeter monitor tone <u>heard adequately</u> 2= Pulse Oximeter monitor tone <u>poorly heard</u> 3= Pulse Oximeter monitor tone <u>not heard at all</u>	<input type="checkbox"/> Radio turned on <input type="checkbox"/> Ventilator in use <input type="checkbox"/> Conversation necessary for the progression of the procedure <input type="checkbox"/> Conversation not necessary for the progression of the procedure <input type="checkbox"/> Suction in use <input type="checkbox"/> Bovie in use <input type="checkbox"/> Bair Hugger <input type="checkbox"/> Other _____
4.	Date _____ Time _____ Room# _____ Procedure _____ Pulse Oximeter Tone Setting _____ Event Scale _____ 1= Pulse Oximeter monitor tone <u>heard adequately</u> 2= Pulse Oximeter monitor tone <u>poorly heard</u> 3= Pulse Oximeter monitor tone <u>not heard at all</u>	<input type="checkbox"/> Radio turned on <input type="checkbox"/> Ventilator in use <input type="checkbox"/> Conversation necessary for the progression of the procedure <input type="checkbox"/> Conversation not necessary for the progression of the procedure <input type="checkbox"/> Suction in use <input type="checkbox"/> Bovie in use <input type="checkbox"/> Bair Hugger <input type="checkbox"/> Other _____

Study Provider: _____

Appendix B

INTER-RATER RELIABILITY TOOL				
<u># Radio Volume</u> <u>Set To</u>	<u>Pulse Oximeter</u> <u>Volume</u>	Provider 1	Provider 2	Provider 3
1	5			
2	5			
3	5			
4	5			
5	5			
6	5			
7	5			
8	5			
9	5			
10	5			

Provider Legend:

1= Provider reports pulse oximeter monitor tone heard adequately2= Provider reports pulse oximeter monitor tone poorly heard3= Provider reports pulse oximeter monitor tone not heard